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Note on "Anomalous Hydrodynamic Drafting of Interacting Flapping Flags"

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We make remarks on Ristroph and Zhang's [*Phys. Rev. Lett.* 101, 194502 (2008)] paper.

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Ristroph and Zhang just showed that [1], inverted drafting could be produced by flexible flags (of which flapping in front reduces fluid forces). As reported in their experiments on *schooling* flapping flags, they found that it is the leader of a group who enjoys a significant drag reduction (of up to 50%), while the downstream flag suffers a drag increase. Thus, they remarked that this counterintuitive inverted drag relationship is rationalized by dissecting the mutual influence of shape and flow in determining drag [1].

The present author, however, likes to issue some comments here about Ristroph and Zhang's experimental procedure and data. Firstly, the technique for measurements of the drag on a flag originated from [2] (cf. Ref. 15: *The flagpole is fixed to a cantilever which bows slightly ($<0.5mm$) under the fluid forcing of the flag. The deflection is measured optically* in [1]; relating support deflection to drag). However, is the net deflection only due to the net force? We know that once there is a net moment (torque included) applied to one end of a (flat) cantilever there will be also a net deflection [3]. Meanwhile, can the net **thrust** (generated) [4] be distinguished from the net drag in [1-2]?

Note that in verifying the drag measuring technique [2] the flow is presumed to be described by the inviscid, incompressible Euler equations [2] by neglecting possible effects of flow compressibility due to thickness variations in the soap film (skin friction or *viscous drag* was also neglected [2]). The latter (compressibility [5] as well as variations of film's thickness [6]) is still being argued [7] and there is a possibility that **Marangoni** flows (due to surface-tension-driven mechanical instability) occur [8] and will induce errors to the experimental measurements reported in [1]. According to [5], the sound speed in the film is $\sqrt{2E_m/\rho_f d_f} \approx 4.3$ m/s (E_m : Marangoni elasticity modulus ($=0.088$ N/m [5]), ρ_f : fluid density, $d_f (=4.7\mu$m [1]) : film thickness). The flow velocity (U) is 2 m/s in [1] and then the Mach number is around 0.46 which means the flow is compressible. The theoretical validation for those relating bending deflection to drag in [1-2] which was based on the incompressible flow thus should be checked again and possibly be modified.

Meanwhile as noted in Ref. 15 of [1], the *minute* bending of the support is optically measured by the same procedure in [2]. How can *The flat cantilever suppresses lateral motion, and streamwise force fluctuations are damped by a viscous dashpot attached to the beam* (cf. Ref. 15 in [1]) be still valid during large-amplitude flapping motions? We know that the identification of an (equilibrium) neutral axis (n.a.) [3] is crucial to the judgement of the bending behavior of a beam (positive or negative deflection?). Can this n.a. be easily found for largely fluctuating support?

The other argue is about the fixed width (9.5 cm) of the planar water tunnel in [1]? How about the **interference** or induced **blockage** [9] (e.g. 4th. flag in Fig. 4a of [1]) between bodies, wakes, and edges of films when large-amplitude flapping occurs (cf. Fig. 1)? What happens once the width (soapy water descends in-between) increases or decreases a little? Is 9.5 cm optimal for the conclusion made in [1] (especially for smaller separations : G/L, cf. [1] for G,L details, where reported significant anomalous inverted drafting appears; cf. Figs. 2 and 4 in [1]). Finally, considering the limitation for the optical resolution in [1] : can the total drag and drag increment be measured separately for $G/L = 0$? How to calibrate the elastic response of the support instantaneously? These issues will dominate the conclusion made in [1]. *Acknowledgements.* The author thanks Ms. Chu Mary and Hsieh Jiu Xiang for their support.

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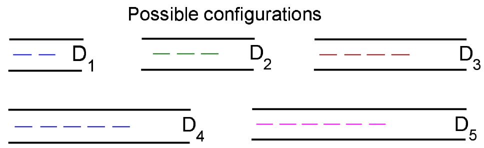

Fig. 1 Schematic set-up for different drag-force baseline calibration of tandem flags. D_0 is for an isolated flag [1]. Ristroph and Zhang neglected the differences in [1] by presuming a universal D_0 for the normalization and baseline comparison even the corresponding configurations are different (say, two and six tandem flapping flags).